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A Wide Ranging Comparison of Routing Protocols in Wireless Sensor Network

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Abstract

Topical advances in the field of designing a micro-sensor units lead to design of several novel protocols exclusively for various applications wireless sensor network (WSN). WSN with huge number of sensor nodes used to congregate information from remote location may be an unreached area and then transmits the gathered data to a sink node, which depends on the application being used. Sensor nodes used have limitation in terms of energy expenditure, storage ability and computation. Routing protocol provides efficient route for data to travel from one node to the other. Such passing and processing of information can be distributed, centralized or local. In this paper, detail comparison of diverse routing protocols based on different parameters in different types of challenges is discussed along with constrains in designing a particular routing protocol. Suggestion on suitable routing protocol for specific WSN application is also provided in such comparison.

Keywords: Wireless sensor Network, protocol, routing, energy efficiency, clustering, distributed, centralized, attribute

INTRODUCTION

Research in different application areas of WSN is rising very rapidly due to recent developments in embedded systems and wireless technologies [1]. WSN has numerous applications in environment monitoring, health monitoring, military, home/offices and many more [2]. Routing protocols plays an essential role in the WSN which are responsible of passing data from one to another end. Figure 1 indicates routing in the field of sensor network along with the required components and interfaces needed for routing like sensor nodes, gateway and server.

The area in which sensor nodes are spread is called field of sensors. Figure 1 indicates how these nodes are interconnected and connected to the server via cloud and gateway. Further, information may pass on to the central computing resource through collection nodes. This in turn passes data to the remote computing resources through Ethernet or wireless network and simultaneously can be saved into database too.

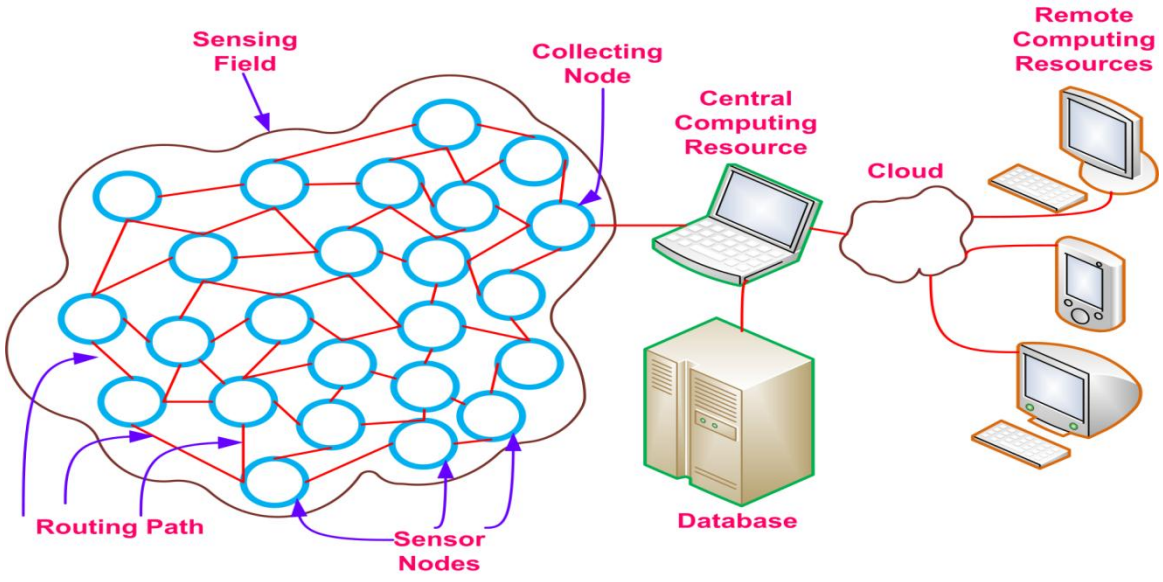

Figure 1. Routing scenario in wireless sensor network

Because of difficulty in assigning unique universal ID numbers for a huge number of wireless sensor nodes, traditional protocols are not suitable for WSN. WSN is network, limited in energy supply as they are operated through small battery, storage, and processing capabilities. It is designed specific to the application. These characteristics of WSN demands of developing efficient routing protocol for WSN [3–4].

The reason behind dynamism of WSN, are energy and mobility. The sensor nodes have restricted source of energy in terms of miniature batteries which tends get drained soon and it is very hard to replace the batteries in some application of remote sensing. Therefore, such application in WSN demands an energy-efficient routing protocol to cope up and balance the energy exist and energy expenditure. The sensor node dies if the protocol is fail to balance the load and energy expenditure amongst sensor nodes. In several applications, it might need for sink node to move over the entire sensor network while deployment of sensor nodes is static. The protocol that works for static sink may not be suitable for mobile sink [5]. Hence looking at such issues, in this paper main design challenges associated with routing protocols of WSN is discussed. After that comparison and classification of various routing protocols in challenging environment is discussed. Selection of routing protocol for a particular WSN application is also discussed.

This paper is structured as follows. Section 2 summarizes literature review of various routing protocol used in WSN. In Section 3 various design challenges associated with designing of routing protocol is discussed. In Section 4 comparison and classification of routing protocol on various parameters is discussed and protocol selection for a particular WSN application is shown.

LITERATURE SURVEY

Various routing protocols for WSN is proposed by researchers in the literature. Every protocol has its pros and cons along with suitable applications where it can be used. In this section survey on various routing protocols that are in use today is discussed.

Heinzelman et al. proposed first hierarchical clustering approach for routing that is called Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol [6]. Advantage of using LEACH is that it balances the load among the cluster heads, unnecessary collisions and excessive energy consumption is avoided by use of individual time slots. LEACH is not suitable to integrate for large-area networks due to its extra overhead because of uneven allocation of cluster head.

Lindsey et al. proposed an improvement over LEACH protocol [7]. This protocol has advantages in terms of it reduces the overhead for cluster's dynamic formation, data transmission is decreased by using chain method and the energy load is dispersed evenly in the sensor network. The disadvantage is that performance can be reduced because of increase in delay for distant nodes due to single chain.

Muruganthan et al. [8] proposed centralized clustering control protocol LEACH-C by modification in LEACH. The advantage of this protocol is that it creates clusters that require a lesser amount of energy for transmitting data. The disadvantage is that it is not applicable to large networks because of extra overhead costs on providing information to the sink or base station.

Stephanie Lindsey and Cauligi S. Raghavendra [5] proposed Power-Efficient Gathering in Sensor Information Systems (PEGASIS) which is also a superior version of LEACH. It is good solution for data gathering applications in WSN. In PEGASIS protocol, every node can transmit to and receive from close neighbour via formation of chain. The data gathered moves from one node to the other until it reaches selected node which transmits data to the sink. Nodes are taking turn in transmitting data or information to the sink node which actually reduce average energy used up by every node per round [5].

To deal with the inadequacy of usual information broadcasting protocols and to conquer their performance deficit, Sensor Protocols for Information via Negotiation (SPIN) like flooding and gossiping are proposed which are data-centric negotiation-based protocols for WSN [9].

The core goal of these protocols is to proficiently distribute data gathered by every individual node to all the other nodes deployed in sensor network. Disadvantage of these protocols is that performance in terms of packet delay, delivery of data and resource utilization rapidly decline with increase in size of the sensor network and the traffic load. This is in general caused by overlapping of geological path and traffic implosion.

A geographic routing protocol delivers a packet to destination based on local information and without the need for any added infrastructure. These protocols perform better than other routing protocols because of the existence of location information.

GAF that is Geographic Adaptive Fidelity [10] is an energy aware routing protocol based on geological location information. GAF protocol optimizes performance of WSN by identifying alike sensor nodes with respect to forwarding packets.

Yu et al. [11] proposed Geographic and Energy Aware Routing (GEAR) uses geological information while distribute queries to appropriate vicinity since data query often include geological attributes. It uses energy aware and geological educated neighbour selection heuristics approach for routing packet towards the destination vicinity.

Directed diffusion (DD) is another data centric routing protocol which is for information congregation and distribution in WSN [12]. The core goal in designing such

protocol is to attain extensive energy savings in order to lengthen the lifetime of the sensor network.

Rumor routing (RR) [13, 14] is same as DD. It is used in application areas where geological routing is not practicable to apply.

TEEN [15] is another hierarchical routing protocol based on cluster formation. It is mostly used in applications where time is critical parameter to be monitored. Disadvantage is that, node has to wait for their time window to transmit data and assigned time window may be shattered if a node has nothing to transmit. APTEEN [16] is an enhanced version of TEEN. It reacts to time critical events and it was developed for hybrid networks.

The Sequential Assignment Routing (SAR) algorithm [21] creates multiple trees. Most nodes belong to such multiple trees and each sensor node records energy left and QoS metric such as delay about each path through it. This permits a node to select one pathway amongst many to pass information to sink node. This chosen path is always with high estimated energy resources.

DESIGN AND OPERATIONAL CHALLENGES FOR ROUTING PROTOCOLS IN WSN

Characteristics of Wireless Sensor Network make it very complicated to develop a routing protocol that works in all applications. Some challenges and issues for routing in WSN are discussed below:

1. Fault tolerance

Wireless sensor network is used in different environments to execute diverse applications and tasks. Because of its sensitivity, routing protocols designed should have the ability to work in the presence of failures.

2. Scalability

WSN comprises huge number of sensors spread across the whole area. Hence routing protocols to be used must be able to operate with such massive number of sensors. They should be designed in a way that they handle all functionalities of the sensor nodes; in turn network's lifetime would become stable.

3. Operating environment

To manage the locations of the sensors is important designing constrain in designing of routing protocols for WSN.

4. Energy consumption

The lifetime is one of the important characteristic of the network which is directly proportional to the total energy consumed by each node [17]. Hefty energy expenditure occurs during route finding and route preservation period. Hence to maximize the network lifetime, protocol essentially to be designed in way that it manages the energy level of all sensor nodes because if a sensor node's energy deplete below a precise threshold, node goes non functional and influence the performance of the entire sensor network and ultimately life cycle of nodes will be less.

5. Data delivery models

Routing protocols should ensure intact data delivery along good accuracy; hence base station can gather the required information about the physical phenomenon right on time. Data delivery models used by a particular routing protocol can be event driven, continuous, query driven and demand driven according to the application in which protocol is used.

6. Deployment of nodes in sensing vicinity

Deploying nodes in sensing vicinity is another important design consideration that greatly influences the performance of the routing protocol. Either it can be self-organized or deterministic in nature. In deploying nodes deterministically, the nodes placement is done manually may be in a grid or structured manner and data routes through predestined paths. Nodes are spread at random and construct an Ad-hoc infrastructure in self organized deployment of nodes.

7. Data aggregation

Data aggregation [18] is a process of uniting of information from various sources. It is used to achieve energy efficiency and to have optimized data transfer. To do so, different signal processing methods are being used. While receiving data from multiple nodes to single or multiple sink nodes [19], there is a chance of receiving similar data. Such data can be used to generate redundant data. Process awareness is needed to perform data fusion. Such fusion technique could be centralized, decentralized and hierarchical.

8. Quality of service

QoS is a very important requirement for any routing protocol used in WSN. A different sensor network has different requirements of QoS. It can be in terms of delivery latency or packet loss. So this should be considered in designing routing protocol for particular application.

9. Limited hardware constraint

Routing protocol should have simple computing procedure and function so that it can be efficiently executed on tiny sensor nodes having limited processing and small storage capacity [20].

10. Self-government

Any centralized entity having rights of controlling of routing mechanism and radio resources is absent as it could easily be attack. This is the reason behind routing procedure needs to be transferred to the nodes of the network [21].

11. Flexibility

There is a high chance of node may stop working due to uncertain environmental conditions or battery failure. Protocols designed for routing should cope with such unforeseen event and substitute route should be revealed.

12. Mobility compliance

Different sort of application could demand mobility of nodes, sink or event to be monitored. Design of a routing protocol should provide support for this mobility requirement.

CLASSIFICATION AND COMPARATIVE STUDY OF VARIOUS ROUTING PROTOCOLS FOR WSN

In this section, comprehensive comparison of widely used routing protocols in WSN is made according to their performance and characteristics as shown widely in Table I and Table II. They can be classified based on topology used by them. Such topology can be flat or hierarchical. In flat networks, every node plays the identical role and all nodes work together to do the task of sensing. In a hierarchical topology, nodes with superior energy are used for sensing, processing and to send information while nodes with little energy are used for the task sensing in the nearness of the target. Flat topology uses contention based scheduling while hierarchical topology uses reservation based scheduling. In flat topology collision overhead is present which is avoided in hierarchical topology. In flat topology routing is complex but optimal while in hierarchical it is less complex but not optimal. Synchronization is not needed in flat topology while global and local synchronization is required in hierarchical. In flat topology fair channel allocation is not guaranteed and energy consumption is not uniform. In hierarchical channel allocation is fair and energy consumption is uniform. The protocols are also classified based on node centric or data centric and source initiated and destination initiated data transfer. Energy consumption of different routing protocols is used as one parameter for comparison.

Routing protocols are also classified based on data aggregation method is used or not and how much scalability they provide [22]. Depending on how data supposed to be transferred, data delivery model could be continuous, event driven, demand driven, query driven or hybrid. Every sensor node transmits data regularly at certain interval in case of continuous data delivery model. Each node will decide report data or not which is based on the pre-determined threshold in case of event driven data delivery model. If this sensed value is beyond the threshold then the node will turn on its transmitter and report it. In demand driven protocols source node creates the route only when needed. Source node would initiate a route discovery process only when it is needed by it. It can also be query driven where protocol responds to queries generated by the sink. The combination of above models can also be used for data delivery and it is called hybrid approach.

Table I also provides information on whether QoS is provided or not and it has any overhead or not. It provides information on which simulator was used to simulate original protocol and application of each protocol. It also gives estimation on network lifetime for each protocol and layer of operation of each protocol. It also specifies mobility for each protocol. Another class of classification can be based on how optimization technique is applied. These techniques are based on attribute, based on energy efficiency, based on location information, based on multipath and QoS, etc [23].

LEACH, TEEN and APTEEN protocols are similar in terms of mobility because mechanism of having fixed BS infrastructure and are cluster based routing protocols. It can be seen from the table of comparison presented that depending on energy consumption and network life time, performance of APTEEN fall in-between TEEN and LEACH. In terms of data transmission also APTEEN outperforms LEACH because it uses threshold values to transmit data in comparison to continuous data transfer in LEACH. TEEN only transmits time-critical data. Directed diffusion (DD) use the flooding technique for queries while in SPIN only interested nodes can query for the data. DD doesn't need network information because each node can only communicate with its neighbours but SPIN needs to maintain a global network topology. SPIN can't guarantee data delivery. SPIN, RR and DD protocols are flat routing protocols and they use meta-data while other protocols don't. GEAR conserves more energy in comparison to directed diffusion. GAF performs well in terms of network parameters like packet loss, latency and it also the sensor network's lifetime by saving on energy expenditure [23]. As it can be seen from the table all protocols are having diverse characteristics and having trade-off between different parameters. Accordingly, these protocols are used in different a application as per its requirement and area to be monitored, which is shown in the last column of Table-II.

Table I. Comparison of various routing protocol -part 1

Protocol	Algorithm Paradigm	Topology	Layer	Energy Consumption	N/W Lifetime	Aggregation of Data	Over Head	Delivery of Data
SPIN	Centralized	Source initiated /Data centric	Network	Low	Good	Yes	Low	Event driven
DD	Centralized	Data centric/ Destination initiated	Network	Low	Good	Yes	Low	Query driven
RR	Distributed	Flat/ Flooding	Network	Low	Very Good	Yes	Low	Query driven
GBR	Distributed	Flat	Network	Low	Very Good	Yes	Low	Hybrid
CADR	Distributed	Flat	Network	Low	Good	Yes	Low	Continuous
COUGAR	Distributed	Flat	Network	Low	Good	Yes	High	Query driven
LEACH	Distributed	Hierarchical / Destination initiated /Node or data centric	Network	High	Very Good	Yes	High	Cluster based Continuous
TEEN & APTEEN	Distributed	Hierarchical	Network	High	Very Good	Yes	High	Cluster based with threshold
PEGASIS	Distributed	Hierarchical	Network	High	Very Good	Yes	Low	Chain based
GAF	Distributed	Hierarchical / Location	Network	Low	Good	No	Mod.	Grid based
SPAN	Distributed	Hierarchical / Location	Network	Low	Good	Yes	High	Continuous
GEAR	Distributed	Location Aware	Network	Low	Good	No	Mod.	Demand driven
SAR	Centralized	Data centric	Network	High	Very Good	Yes	High	Continuous
SPEED	Centralized	Location/Data Centric	Network	Low	Good	No	Less	Geographic

Table II. Comparison of various routing protocol -part 2

Protocol	Mobility	Scalability	Base of Applied Optimization Technique	Simulation Environment	Application
SPIN	Supported	Partial	Attribute Multipath	NS-2	Intrusion detection, critical infrastructure protection
DD	Limited	Partial	Attribute Multipath	NS-2	Environment monitoring
RR	Very Limited	Good	Attribute	LecsSim	Environment monitoring
GBR	Limited	Partial	Attribute	MATLAB	Health
CADR	No	Partial	Attribute	Math. Model	Environment monitoring
COUGAR	No	Partial	Attribute	NS-2	Environment monitoring
LEACH	Fixed BS	Good	Attribute	MATLAB NS-2 OmNet	Health
TEEN & APTEEN	Fixed BS	Good	Attribute	MATLAB NS-2 OmNet	Home/Office
PEGASIS	Fixed BS	Good	Attribute QoS	MATLAB NS-2 OmNet	Health
GAF	Limited	Good	Attribute	MATLAB NS-2 OmNet	Habitat monitoring, Military surveillance
SPAN	Limited	Partial	Attribute	MATLAB NS-2	Habitat monitoring
GEAR	Limited	Partial	Attribute	Test bed	Home/Office
SAR	No	Partial	Attribute ,QoS	Parsec	Production/Commercial
SPEED	No	Partial	Attribute	GloMoSim	Health

CONCLUSION

Routing and communication and information among nodes and to sink node in WSN has established a bundle of interest in topical years because of its distinctive operative and design challenges compared to conventional routing of data or information in existing wired networks. Wireless sensor networks are very application specific that makes it difficult to design proficient routing protocols for sensor networks. So in this paper, a wide-ranging analysis of diverse routing protocols in wireless sensor networks is presented along with their design constrains. The routing protocols are classified using different parameters like topologies they used, amount of power they consumed, data delivery model they use, scalability, network lifetime, etc. Comparison of almost 15 different protocols based on said parameters is provided in this paper. It can be inferred that choice of routing protocol depends on application, area to be monitored and no single routing protocol is suitable in all applications.

REFERENCES

[1] M. Gholipour, A. T.Haghighat, and M. R. Meybodi :Opportunistic Routing Algorithm for Relay Node Selection in Wireless Sensor Networks. InIEEE Transactions on Industrial Informatics, Vol. 11, No. 1, Pages 112 – 121, February 2015.

[2] A. Tiab and L. B. Medjkoune: Routing in Industrial Wireless Sensor Networks: A Survey. In Chinese Journal of Engineering, Vol. 2014, Pages 1 – 7, 2014.

[3] D. Zhang, G. Li, K. Zheng, X. Ming, and Z. H. Pan: An Energy-Balanced Routing Method Based on Forward-Aware Factor for Wireless Sensor Networks. In IEEE Transactions on Industrial Informatics, Vol. 10, No. 1, Pages 766 – 773, February 2014.

[4] T. Rault, A. Bouabdallah, and Y. Challal: Energy Efficiency in Wireless Sensor Networks: A Top-Down Survey. In Computer Networks, Vol. 67, No. 1, Pages 104 – 122, July 2014.

[5] M. Azharuddin and P. K. Jana: A Distributed Algorithm for Energy Efficient and Fault Tolerant Routing in Wireless Sensor Networks. In Wireless Networks, Vol. 21, No. 1, Pages 251 – 267, January 2015.

[6] W. Heinzelman, A. Chandrakasan, and H. Balakrishnan: Energy-Efficient Communication Protocol for Wireless Microsensor Networks. In 33rd Hawaii International Conference on System Sciences (HICSS '00), Pages 10 – 19, January 2000

[7] S. Lindsey and C. Raghavendra: PEGASIS: Power-Efficient Gathering in Sensor Information Systems. In IEEE Aerospace Conference, Pages 1125 – 1130, 2002

[8] S. D. Muruganthan, D. C. F. Ma, B. Rollyi, and A. Fapojuwo: A centralized energy-efficient routing protocol for wireless sensor networks. InIEEE Radio Communications, Vol. 43, No. 3, Pages 8 – 13, 2005.

[9] J. Kulik, W. R. Heinzelman, H. Balakrishnan: Negotiation-Based Protocols for Disseminating Information in Wireless Sensor Networks. In Wireless Networks, Vol. 8, 2002, pp. 169–185.

[10] Y. Xu, J. Heidemann, D. Estrin: Geography-informed Energy Conservation for Ad-hoc Routing. In Proceedings of the Seventh Annual ACM/IEEE International Conference on Mobile Computing and Networking 2001, pp. 70-84.

[11] Y. Yu, D. Estrin, and R. Govindan: Geographical and Energy-Aware Routing: A Recursive Data Dissemination Protocol for Wireless Sensor Networks. In UCLA Computer Science Department Technical Report, UCLA-CSD TR-01-0023, May 2001.

[12] C. Intanagonwiwat, R. Govindan, D. Estrin: Directed Diffusion: A Scalable and Robust Communication Paradigm for Sensor Networks. In Proceedings of the 6th ACM International Conference on Mobile Computing and Networking (MobiCom'00), Boston, MA, Aug. 2000, pp. 56–67

[13] Braginsky, D.; Estrin, D. Rumor: Routing algorithm for sensor networks. In Proceedings of the First Workshop on Sensor Networks and Applications (WSNA), Atlanta, GA, USA, October 2002

[14] Debnath Bhattacharyya, Tai-hoon Kim and Subhajit Pal: A Comparative Study of Wireless Sensor Networks and Their Routing Protocols. In open access sensor journal, ISSN 1424-8220, 2010

[15] Manjeswar, A.; Agrawal, D.P. TEEN: A protocol for enhanced efficiency in wireless sensor networks. In Proceedings of 1st International Workshop on Parallel and Distributed ComputingIssues in Wireless Networks and Mobile Computing, San Francisco, CA, USA, 2001; p. 189.

[16] Manjeswar, A.; Agrawal, D.P. APTEEN: A hybrid protocol for efficient routing and comprehensive information retrieval in wireless sensor networks. In Proceedings of 2nd International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing, Fort Lauderdale, FL, USA, April 15–19, 2002; pp. 195-202.

[17] K. Akkaya and M. Younis: A Survey on Routing Protocols for Wireless Sensor Networks. In Ad Hoc Networks, Vol. 3, No. 1, Pages 325 – 349, 2005.

[18] Heinzelman, W.B. Application-Specific Protocol Architectures for Wireless Networks. PhD. thesis, Massachusetts Institute of Technology. Cambridge, MA, USA, June 2000.

[19] T. K. Jain, D. S. Saini, and S. V. Bhooshan. Lifetime Optimization of a Multiple Sink Wireless Sensor Network through Energy Balancing. In Journal of Sensors, Vol. 2015, Pages1 – 6, 2015.

[20] Jamal, N.; E. Kamal, A.-K.A. Routing techniques in wireless sensor networks: A survey. In IEEE Wireless Communication. 2004, 11, 6-28.

[21] K. Sohrabi and J. Pottie: Protocols for Self-Organization of a Wireless Sensor Network, IEEE Pers. Commun., vol. 7, no. 5, pp.16–27 (2000).

[22] Biradar, R. V., Patil, V. C., Sawant, S. R., & Mudholkar, R. R. (2009). Classification and comparison of routing protocols in wireless sensor networks. Special Issue on Ubiquitous Computing Security Systems, 4(2), 704-711.

[23] Villalba LJG, Orozco ALS, Cabrera AT, Abbas CJB. Routing Protocol in Wireless Sensor Networks. Sensors (Basel, Switzerland). 2009:9(11):8399-8421